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NOTES ON TERTIARY DEPOSITS NEAR COALINGA OIL FIELD AND THEIR STRATIGRAPHIC RELATIONS WITH THE UPPER CRETACEOUS

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The work of the California division of the geological department of the Southern Pacific Company during the spring of 1910 was devoted in part to the differentiation and careful definition of the oil-bearing formations of the Coalinga district and the area lying north of it and the mapping of the surface exposures of each as accurately as conditions would permit. Two field parties were engaged in this work, one of them comprising Mr. J. A. Taff, assisted by Mr. B. L. Cunningham, and the other Mr. F. M. Anderson, assisted by Messrs. G. C. Gester and E. A. Hardy. The work begun here is being extended to cover the west side of the San Joaquin Valley. As soon as the collections and field data have been properly studied, it is hoped that papers may be published by these geologists giving the geological details fully, but, since such publications may be delayed, I have arranged the following statement of some of the results of the early work, based on their preliminary reports and maps.

PREVIOUS WORK

The first two publications based directly upon the work of this department in this area were those by Mr. Frank M. Anderson, entitled "A Stratigraphic Study in the Mount Diablo Range of California,"¹ in 1905, and "A Further Stratigraphic Study in the Mount Diablo Range of California,"² in 1908. Prior to our work, we have only the reports of Mr. W. L. Watts in *Bulletins Nos. 3* and *19* of the California State Mining Bureau and the paper of Mr. George H. Eldridge in *Bulletin No. 213* of the United States

¹ *Proc. California Acad. Sci.*, 3d series, Geology, II (1905), 156-248.

² *Ibid.*, 4th series, Geology, III (1908), 1-40.

Geological Survey. Later publications on the area are those of Messrs. Arnold and Anderson in *Bulletins Nos. 357, 396, and 398* of the United States Geological Survey.

A careful study of these publications indicates that no one has been able clearly to differentiate the basal beds of the Tertiary from the upper beds of the Cretaceous, and that the parting as drawn was purely suppositional. The Tejon was the only member of the Eocene positively identified, although Mr. Anderson suggests the possible Martinez age of some lower beds.

In the Neocene, the different divisions were fairly well established and while the Monterey or lower middle Miocene fauna seemed lacking, the sediment is probably represented by a peculiar formation called the Big Blue and the equivalency of the two was suggested.

THE CRETACEOUS-TERTIARY CONTACT

Through much of this territory the uppermost Cretaceous is represented by shales and the basal Tertiary is also shaly in character. This fact has made it difficult to clearly distinguish the one from the other or to mark their parting. In the earlier publications it was supposed that there was no appreciable break in the sedimentation of the two periods, and that there was also an overlapping of faunas. This latter supposition was disproved by the work of Messrs. Stanton, Merriam, and Weaver in their studies of the region north of Mount Diablo, and we now have also conclusive proof of great stratigraphic breaks, not only between the Cretaceous and the Eocene, but also between the formation to which these basal Eocene beds belong and the overlying Tejon, which was originally supposed to represent practically the entire Eocene of the California section.

The evidence of the stratigraphic break between the Cretaceous and Eocene is somewhat more clearly shown at a point outside this territory than has yet been proven within it, and our study of this section enables us to trace the parting in the territory under discussion.

Some six or seven miles southwest of Antioch and in the eastern foothills of Mount Diablo, there is a short canyon where a slight sipe of oil was found, from which circumstance it was given the

name of Oil Canyon. A few years ago, two or three wells were sunk here in a search for oil, but failed to develop it. The north bank of this canyon gives us very distinctly the relations of the Cretaceous and Eocene.

The Chico is represented through the greater part of its exposure by a purple shale identical in appearance with that of the Coalinga region. Through a part of this shale there are beds of concretionary clayey limestone with ammonites and other Chico forms. Above this, the concretions, scattered irregularly through the shale, take the form of a very fine-grained blue limestone which weathers perfectly white. Toward the eastern end of the exposure this purple shale is overlain by a gray sandstone weathering brown. It is rather coarse grained as a whole, even conglomeratic in places, and is quite massive in structure. It carries limy concretions which contain fragments of *Inocerami*.

The lowest Eocene or Martinez deposit begins with a brown sand and sandy shale, more or less glauconitic, with limy concretions carrying a Martinez fauna. Higher in the section the shaly nature of the beds becomes more pronounced and they carry concretionary nodules of limestone and ironstone. Near the center of the section, as exposed here, there is a band of coarse red sandstone with some greensand, green mica, and casts of fossils. It is only a few feet in thickness and is succeeded by brown shales which carry more and more clay toward the top and more numerous and larger concretions of clay-ironstone, and lime.

At the west end of this section, opposite the head of Oil Canyon, the Martinez sandy shales rest on the Chico purple shale immediately above the band of the clayey limestone with ammonites. Going eastward a mile, higher and higher beds of the Chico shale appear under the Martinez until, at a horizon fully 125 feet stratigraphically above the first observed contact, the point of the sandstone wedge comes in and thickens until there is a body of at least 80 feet of it exposed below the Martinez.

While the exact point of contact is difficult to place where the two shale beds come together, it is entirely possible to say within a few feet of such contact, "This is Chico," or "This is Martinez," from their dissimilarity. On the sandstone, however, the contact

is sharply defined. There are numerous borings in the top of the Chico sandstone which are filled with the fine gravel and sand of the Martinez, and covering the surface is a layer of glauconitic sandy material with imprints of small shells, which is the base of the Martinez. This grades upward into the sands and sandy shales with concretions and nests of Martinez fossils.

With this section in mind, the tracing of the contact in the area north of Coalinga is not so difficult. The top of the Chico comprises purple shales and concretionary sands, and the base of the Martinez, while of much more argillaceous character than at Oil Canyon, is yet distinct.

MARTINEZ FORMATION

To Messrs. Stanton, Merriam, Weaver, and Dickerson¹ is due the credit of demonstrating in the Mount Diablo region the existence below the Tejon of a series of beds of Eocene age, which is clearly distinguishable from that terrane by its characteristic fauna and unconformable relationship. This has been named the Martinez, but only meager accounts of its stratigraphy are available and its existence was recognized at only a few localities.

Our work now proves that this lower member of the Eocene is of very considerable extent southward on the west side of San Joaquin Valley; that it consists of three or more clearly defined members, and that, in addition to the unconformity already described between it and the Cretaceous, there also exists a decided unconformity between it and the overlying Tejon.

The Martinez is well developed in Townships 17 and 18 South, Ranges 13 and 14 East, in the Salt Creek-Cantua region, and comprises a basal bed of chocolate shales with glauconitic sands overlain by yellow sands and conglomerates and these overlain in turn by other chocolate shales. The generalized section of the Martinez in this particular area may be stated as follows:

¹ T. W. Stanton, "The Faunal Relations of the Eocene and Upper Cretaceous on the Pacific Coast," *17th Rep. U.S. Geol. Survey* (1895-96), pp. 1011-60.

J. C. Merriam, "The Geologic Relations of the Martinez Group of California at the Typical Locality," *Jour. Geol.*, V (1897), 767-75.

C. E. Weaver, "Contribution to the Paleontology of the Martinez Group," *Univ. Calif. Publ. Bull. Dept. Geol.*, IV (1905), 101-23.

Roy E. Dickinson, "Stratigraphic and Faunal Relations of the Martinez Formation to the Chico and Tejon North of Mt. Diablo," *Univ. Calif. Publ. Bull. Dept. Geol.*, VI (1911), 171-77.

3.	Upper chocolate shales, comprising bluish shales at top, grading down into chocolate or brown shales which wea- ther to clays.	ft.
	These rest upon other chocolate shales which become sandier toward bottom. These shales vary in thickness	600-900
2.	Yellow sand and conglomerate.	
	Bluish sandy shales and thin sandstone, variable in thick- ness.....	200
	Massive yellow sandstone with large dark brown segrega- tions and concretions and some layers of bluish sandy shale	300
	Fine sand with local beds of conglomerate interbedded with blue and brown shales; a considerable amount of glauconitic material at base.....	300
1.	Lower chocolate shales.	
	Beds of chocolate and brown shale with small ferruginous and limy concretions and layers of glauconitic sand...	1,000
		2,700

Mr. Anderson reports the following forms collected from the top of the lower chocolate shales at a locality on Salt Creek in the SW $\frac{1}{4}$ of NW $\frac{1}{4}$ Section 25, Twp. 18 S., R. 14 E.:

Corbula horni Gabb
 Meretrix fragilis Gabb
 Leda gabbi Conrad
 Margaritella angulata? Gabb
 Helicaulax costata Gabb
 Ataphrus crassus? Gabb
 Neverita globosa Gabb
 Arca horni Gabb
 Architectonica horni Gabb
 Rimella canalifera Gabb
 Bulla horni Gabb
 Nucula truncata Gabb
 Modiola ornata Gabb
 Pectunculus sp.
 Discohelix californica Weaver
 Turritella pachecoensis Stanton
 Cucullea matthewsoni Gabb
 Arca biloba Weaver
 Dentalium sp.
 Cylichna costata Gabb
 Barbatia morsei Gabb
 Spirogllyphus tejonensis Arnold
 Pleurotoma fresnoensis Arnold
 Corbula paralis Gabb
 Venericardia alticosta Gabb
 Numulites
 Shark teeth

While a number of these forms are common to the Tejon and Martinez, there are several that are characteristic of the Martinez, and this, taken with the relation of these beds to the overlying Tejon, makes it necessary to refer them to the Martinez.

The greatest surface exposure of these beds in this area is found in Twp. 17 S., R. 13 E., where except for a band of Cretaceous along the south line they form the surface rocks for the entire southern half of the township. The exposure of the lower shale is only a half to three-quarters of a mile in width and the upper shale occupies a similar belt, but the yellow sandstone member has an average breadth of exposure of nearly two miles. On the eastern line of this township this is narrowed to half a mile and the three members cross the north line of Twp. 18 S., R. 14 E., with a total width of less than two miles. This is again narrowed toward the southeast until in Section 23 of this township the upper brown shale and the greater part of the yellow sand has been removed by pre-Tejon erosion, and, south of that point, so far as it occurs, the Martinez is represented beneath the Tejon only by the basal shale with a thin band of yellow sand overlying it through a part of the area.

TEJON FORMATION

The series of sediments here assigned to the Tejon admit of separation into two distinct members; the lower of white sand and conglomerate carrying a fauna in all respects identical with that of the original Tejon locality, and an upper member of white shale which is not so fossiliferous and which, as has been suggested by different investigators in this area, may in part or as a whole represent the Oligocene.

The general section of the Salt Creek-Cantua region is as follows:

5. White shale.		
White fissile organic shales, containing fish scales, teeth, foraminifera, etc.	ft.	
	500	
Lenses of fine brown sand.		
White shale with local thin sandy strata	1,000	
Local friable sand.	0-30	
Pink to white shale.	200	
Bluish sandy shales grading up into pink shales.	40	
	—	1,770

4. White sandstone and conglomerate.	
Yellowish to white, usually fine sand	100-160
White massive sandstone and conglomerate with whitish shale inclusions at the base	20-40
	200

In this portion of the field the base of the Tejon is a fossiliferous conglomerate and sandstone which shows distinct unconformity with the underlying Martinez. Thus, on the east line of Section 17, Twp. 19 S., R. 15 E., the base of the conglomerate is upon an oxidized zone and the massive sandy shale immediately below the conglomerate is cut by numerous burrows that appear to have been made by crustaceans, in some cases extending down to a depth of three feet. These burrow holes have been filled with ferruginous sand and gravel conglomerates that are connected directly with the overlying conglomerate. To the northwest in Twp. 17 S., R. 13 E., where the conglomerate rests upon the upper shale of the Martinez, it contains shale inclusions at the base.

Here, as elsewhere, the Tejon carries coal locally. These coal seams occur near the base and as thin stringers higher in the section, but in this area they have not proven to be of economic value. It is interesting to note that the coal north of the Cantua occurs above the conglomerate, which we here make the base of the Tejon, while west of Coalinga it occurs below a similar conglomerate. At the Oil Canyon locality, described under the Martinez, the Tejon beds are coal bearing only in their upper portion, that is, from 250 to 300 feet below the top, while below the coal-bearing beds there is probably a thickness of 600 feet of shale before the heavy conglomerate, which there marks the base of the formation, is reached. For this reason, it would seem that either this member of the Tejon has much decreased in thickness or that only the upper portion of the beds as seen at Oil Canyon are represented there.

While the exposures of the upper white shale are excellent through Coalinga-Salt Creek-Cantua area, the few fossils obtained during this examination do not give any more definite grounds for determining its age than those before known. It apparently succeeds the lower member of the Tejon without unconformity and is highly unconformable with the succeeding Vaqueros beds of Lower Miocene age.

MIOCENE

The character and divisions of the Miocene in this region have been quite fully described in the publications referred to and especially by Messrs. Arnold and Anderson in the Bulletins of the United States Geological Survey. The divisions present in this area are as follows:

5. Etchegoin
4. Jacalitos
3. Santa Margarita
2. Monterey?
1. Vaqueros

1. VAQUEROS

The Vaqueros comprises all beds found between the Tejon and the Big Blue, the basal non-fossiliferous member of Santa Margarita of Arnold. It is predominatingly sandy, with conglomerate at base, and very fossiliferous as a whole. It lies with marked unconformity upon the Tejon. The basal unconformity which has been described and fully illustrated elsewhere is marked in Twp. 17 S., R. 14 E., by the absence of its lower beds, the upper portion resting directly on the Tejon white shale.

2. MONTEREY

The series of light-gray, fine-grained sand and clay that appear bluish when moistened, which lies between the Vaqueros and Santa Margarita, has been called the "Big Blue" and its possible Monterey age has been suggested by Arnold, who classed it tentatively with the Santa Margarita. It has a thickness of nearly 300 feet in the oil field, but appears to be somewhat thinner toward the northwest. It is clearly separated from the Vaqueros beds below and the Santa Margarita above.

In Twp. 17 S., R. 14 E., it occurs as bluish shales that in places are variegated reddish and yellow, succeeded by sandy bluish shales intermixed with gravel, having a total thickness of about 200 feet. The shales are unfossiliferous here as elsewhere, but are easily separable from the Santa Margarita, since the basal conglomerate of that formation contains a wealth of typical Santa Margarita fossils.

The stratigraphic position of the Big Blue north of Coalinga is

the representative, in part at least, of the Monterey in the Sunset-McKittrick field. At its most southern exposure in Section 29, Twp. 19 S., R. 15 E., just before it is lost under the overlapping Jacalitos, it appears as a white, apparently organic, silicious shale very similar in appearance to and in the same stratigraphic position as the shale of the Monterey where it emerges from this overlap in the southern part of the Coalinga field. That the Big Blue is the attenuated northern and more littoral representation of the Monterey is clearly evident.

SANTA MARGARITA

The base of this division of the Miocene in the Coalinga field is marked by the *Tamiosoma* zone and is overlain by sands and gravels with a total thickness of 600 feet. It is overlain unconformably by the later formations. These features continue northward but gradually the lower member grades into a remarkable conglomerate. On Salt Creek thick beds of heavy serpentine conglomerate occur in it and near the south edge of Twp. 17 S., R. 14 E., it becomes a variable deposit of coarse irregular serpentine breccia with beds of conglomerate, sands, and shale. The size of the material gradually decreases toward the northward along the outcrop and the fragments show greater wear. The beds contain the typical Santa Margarita fossils and are overlain by the sandy clays and gravel beds of its upper member.

JACALITOS AND ETCHEGOIN

The beds described under these names in the Coalinga field and supposedly separable there by the fossils contained in them continue northward, but generally without the fossils, so that it is difficult to separate the two in Twps. 18 N., R. 14 and 15 E., and 17 N., R. 13 and 14 E., and in fact to distinguish between them and the overlying Pliocene, the entire measures as exposed being a variable series of sandy clays, sands, and gravel beds aggregating 1,800 to 2,000 feet in thickness below the alluvial deposits to the east.

We were unable clearly to differentiate the Jacalitos and Etchegeoin in the Coalinga region, since we found more than one *Glycymenis* zone in them, neither of which was mappable throughout

the field, and the Jacalitos-Etchegoin appears to be one progressive series overlapping far upon older rocks during a period of long-continued submergence.

RESULTS

Taking the results as a whole, it is probable that the most prominent and important geological fact brought to light is the continued and repeated oscillations of this part of the territory in Tertiary time, as opposed to the former idea of a practically uninterrupted sedimentation—proving that land areas existed here at the end of the Chico, the Tejon, and the Santa Margarita, and probably at the end of the Martinez and the Monterey.

The most extensive of these emergences was that between the Cretaceous and Tertiary; the next that between the Eocene and Miocene. Those between the Martinez and the Tejon and that at the end of the Monterey are not so definitely made out as yet, but there is good evidence of their existence.

The results of temporary oscillations occurring between or during these times are clearly apparent in the local unconformities existing in the various formations.